

Use of an external ring fixator for correction of an acquired angular limb deformity in a donkey

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- ▶ Numerous techniques for surgical correction of angular limb deformities in horses involving an osteotomy of the affected bone and stabilization with an internal fixation device have been described. However, because the osteotomy typically has to be performed at the level of the physis, leaving little bone between the physis and the nearest joint, stabilizing the osteotomy by use of internal fixation devices may be difficult.
- ▶ In horses with severe chronic angular limb deformities, the amount of soft-tissue contracture may make it impossible to correct the deformity during a single procedure without causing stretch injuries to the adjacent tendons and neurovascular structures.
- ▶ Adjustable external ring fixators incorporating hinged rods on 1 side of the limb and an angular motor assembly on the other may be useful for treatment of severe chronic angular limb deformities in younger equids, because they allow for gradual correction of the deformity.

A 5-month-old 52.3-kg (115-lb) male donkey was referred to the University of Georgia Veterinary Teaching Hospital for evaluation of a grade 4 of 5 left forelimb lameness. The donkey had become caught in wire fencing approximately 4 weeks prior to admission. The owner reported that the donkey would not bear weight on the left forelimb immediately after the injury, but the lameness had gradually improved. Prior treatment included administration of penicillin G procaine and phenylbutazone. On radiographs obtained by the referring veterinarian, proximal diaphyseal fractures of the radius and ulna were evident.

At admission, the donkey was bright and in good body condition. A grade 4 of 5 left forelimb lameness was evident. A 30° valgus deformity of the left forelimb with approximately 20° of external rotation was evident; the deviation appeared to originate at the proximal aspect of the antebrachium. Palpation of the forelimb revealed diffuse firm enlargement of the proximomedial aspect of the radius. There was no palpable laxity or crepitus of the elbow joint, nor was there palpable laxity or crepitus in the area for the fractures evident on the referring veterinarian's radiographs. No wounds were evident. Radiography of the proximal part of the antebrachium revealed a chronic healing Salter-Harris type-II fracture of the proximal radial physis and a transverse fracture of the adjacent ulna (Fig 1).

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Figure 1—Lateromedial (top) and cranio-caudal (bottom) radiographic projections of the left elbow joint and antebrachium in a 5-month-old donkey with an angular limb deformity secondary to malunion of a Salter-Harris type-II fracture of the proximal radial physis and an adjacent transverse fracture of the ulna.

Surgical correction of the deformity was recommended because of the severity of the deformity and the risk of elbow joint disease. On the basis of chronicity and location of the fracture and the degree of deformity, gradual correction of the deformity with an adjustable hinged external ring fixator^a was advocated.

Prior to surgery, the severity of angular deformity was measured on the cranio-caudal radiographic projection. A line was drawn parallel to the long axis of the radius centered on the bone. A second line was drawn perpendicular to the elbow joint centered on the distal aspect of the humerus. The intersection of the 2

lines was determined to be the point of maximal deformity, and the angle formed by the intersection of the 2 lines was determined to be the angle of the deformity. Because of the proximal location of the deformity, the plan was to place only 1 fixator ring proximal to the point of maximal deformity and 2 rings distal. An osteotomy of the radius perpendicular to the long axis of the bone at the point of maximal deformity was planned. The planned configuration of the hinged rods and angular motor assembly was that of an isosceles triangle. The hinged rods were to be placed on the medial aspect of the limb at the 8:00 and 10:00 positions; the angular motor assembly was to be placed on the lateral aspect of the limb at the 3:00 position.

The donkey was given penicillin G potassium (22,000 U/kg [10,000 U/lb] of body weight, IV), gentamicin (6.6 mg/kg [3 mg/lb], IV), phenylbutazone (4.4 mg/kg [2 mg/lb], IV), and tetanus toxoid prior to surgery. It was then anesthetized and positioned in dorsal recumbency with the left forelimb in full extension. Hair on the limb was clipped from the midportion of the metacarpus to a point dorsal to the scapula, and the skin was prepared routinely. The limb was draped, and a stab incision was made over the lateral radial tuberosity. A 5/64-in (2.0-mm) pin was driven through the proximal radial epiphysis in a lateral-to-medial direction, parallel and 2 cm distal to the elbow joint. The proximal fixator ring was fixed to this pin with slotted wire fixation bolts, and the ring was visually adjusted so that it was perpendicular to the craniocaudal plane of the radius. A cranially placed fixation bolt was used as a wire guide to drive a second pin through the proximal radial epiphysis in a cranial-to-caudal direction 90° to the first pin. The second pin was also fixed to the ring with fixation bolts, and approximately 90 to 100 kg of tension was applied to each of these pins, using a wire tensioner. A third pin was placed in a cranial-to-caudal direction 7 cm distal to the point of maximal deformity. This pin was attached to a second fixator ring, and tension was applied to the pin. The ring was then rotated about the axis of the craniocaudal pin until it was perpendicular to the portion of the radius distal to the point of maximal deformity and formed a 30° angle with the proximal fixator ring. The ring was secured in this position by inserting a pin in a lateral-to-medial direction and attaching the pin to the ring. An angular motor assembly was placed on the lateral aspect of the limb between the 2 fixator rings. The craniomedial and caudomedial aspects of the rings were joined with hinged rods so that the 2 hinged rods formed an isosceles triangle with the motor rod. A third ring was then placed in similar fashion to the second ring 2 cm distal and parallel to the second ring. The 2 distal rings were fixed together with bolts through spacers at 4 equidistant points around the rings.

A 5-cm longitudinal skin incision was made over the dorsal aspect of the radius between the proximal and middle rings. The extensor carpi radialis and common digital extensor muscles were retracted, and the periosteum of the radius was incised, elevated, and retracted. A transverse osteotomy was performed 3 cm distal to the original fracture, using a pneumatic oscil-



Figure 2—Photograph of the donkey in Figure 1 following osteotomy of the radius and ulna and placement of an adjustable external ring fixator. Notice the hinged rods on the medial aspect of the limb and the angular motor assembly on the lateral aspect.

ating saw.^b The caudal aspect of the ulna was exposed in a similar manner, an ulnar osteotomy was performed, and the radial osteotomy was completed. The site was liberally lavaged with sterile saline (0.9% NaCl) solution, and the wounds were closed in a routine fashion. Triple antibiotic ointment was placed around the pin-skin interfaces. The skin-ring gap was loosely packed with sterile gauze sponges, and a sterile elastic bandage was placed over the fixator. The donkey recovered from anesthesia without complications and was able to stand with the fixator in place (Fig 2). On radiographs obtained after surgery, it appeared that pin placement and alignment were acceptable, and the osteotomies of the radius and ulna were complete (Fig 3).

Gentamicin (6.6 mg/kg, IV, q 24 h) was administered for 2 days after surgery, and penicillin G potassium (22,000 U/kg, IV, q 6 h) and phenylbutazone (4.4 mg/kg, IV, q 12 h) were administered for 5 days. The pin fastener bolts were checked daily for signs of loosening. The bandage covering the fixator was changed daily. During each bandage change, the pin-skin interfaces were cleaned with a dilute povidone-iodine solution followed by application of triple antibiotic ointment around the interfaces.

Distraction of the osteotomies was initiated 24 hours after surgery. One complete rotation at the angular motor assembly resulted in 1 mm of distraction at



Figure 3—Craniocaudal radiographic projection of the left elbow joint and antebrachium of the donkey in Figure 2 obtained immediately after placement of the external ring fixator and osteotomy of the radius and ulna.

the osteotomy sites.^a On days 2 and 3, 1 mm of distraction was obtained once a day; on days 4 through 12, 1 mm of distraction was obtained every 12 hours; and on days 13 through 19, 1 mm of distraction was obtained every 8 hours. Thus, total distraction was 41 mm. Radiography 21 days after surgery indicated that the angular deformity had been completely corrected, and regenerate callus was beginning to form at the osteotomy sites. Under standing sedation, the angular motor assembly and hinged rods were then removed, and the proximal and middle fixator rings were connected, parallel to each other, with bolts through spacers.

Radiographs were obtained every 14 days to evaluate formation of the regenerate callus and to determine when the fixator would be removed. Thirty-four days after surgery, a slight exudate was evident at the dorsal pin-skin interfaces of the proximal and middle pins, and the proximal portion of the limb was more swollen than previously. A sample of the exudate was obtained and submitted for bacteriologic culture and susceptibility testing. The donkey was treated with trimethoprim-sulfamethoxazole (20 mg/kg [9 mg/lb], PO, q 12 h) for 6 days, the bandage was changed, and the wounds were cleaned daily. The following week, the donkey was febrile (39.6 C [103.2 F]) and lethargic and less willing to use the limb. The amount of the exudate from the wounds had also increased. A blood

sample was collected and submitted for a CBC. Abnormalities included mild anemia (5.23×10^6 RBC/ l), low PCV (24.4%), low hemoglobin concentration (8.8 g/dl), and high fibrinogen concentration (600 mg/dl). Because of the worsening clinical signs, oral administration of trimethoprim-sulfamethoxazole was discontinued, and treatment with penicillin G potassium (22,000 U/kg, IV, q 6 h) and gentamicin (6.6 mg/kg, IV, q 24 h) was initiated. Radiographs obtained 48 days after surgery revealed loosening of the pins indicated by lysis surrounding the pin-bone interface. Although the osteotomies were not completely healed, there was smooth regenerate callus bridging the sites. Because of loosening of the pins, persistent drainage at the pin-skin interfaces, and worsening of the lameness, the fixator was removed at this time. Bacterial culture of the exudate from the pin-skin interfaces yielded a light growth of *Staphylococcus intermedius* susceptible to amikacin, clindamycin, enrofloxacin, and rifampin. Intravenous antibiotic administration was discontinued, and the pin holes were treated daily by flushing with 500 ml of 0.9% NaCl containing 1 g of amikacin and applying a triple antibiotic ointment prior to bandaging.

The limb was bandaged and placed in a full-limb splint. The bandage was changed daily to allow for wound care. The amount of exudate decreased rapidly, the wounds healed, and the lameness improved. On follow-up radiographs obtained 76 days after surgery, considerable bridging callus at the osteotomy sites was evident, and the splint was removed (Fig 4). A follow-up examination 3 months later revealed correction of the valgus and rotational deformities, healing of the osteotomy sites, and resolution of the lameness.

Use of an external ring fixator resulted in successful repair of the angular limb deformity in the donkey described in the present report. During the distraction phase of the repair, substantial gapping of the medial aspects of the radial and ulnar osteotomies was evident on radiographs. This was attributed to placement of the hinges proximal to the plane of the osteotomy. For the osteotomies to have opened only on the lateral aspect, the hinges would have to have been placed exactly in the plane of the osteotomies. Because the hinges were proximal to the plane of the osteotomies and the medial aspect of the osteotomies gapped open during distraction, the limb would have been lengthened by a distance equal to the distance between the plane of the osteotomies and the axis of the hinges. However, we corrected for this by periodically shortening the hinge rods after radiographic evaluation, allowing for collapse of the medial aspects of the osteotomies. We did not detect any complications associated with this additional manipulation of the fixator. The small rotational deformity of the distal radius with relation to the proximal radius was corrected acutely at the time of surgery. The remaining rotational deformity, which was the result of abnormal hoof growth, was corrected postoperatively with frequent hoof trimming and correction of the valgus deformity.

The rate and rhythm of distraction of the osteotomies were selected on the basis of how easily the angular motor assembly could be turned and how

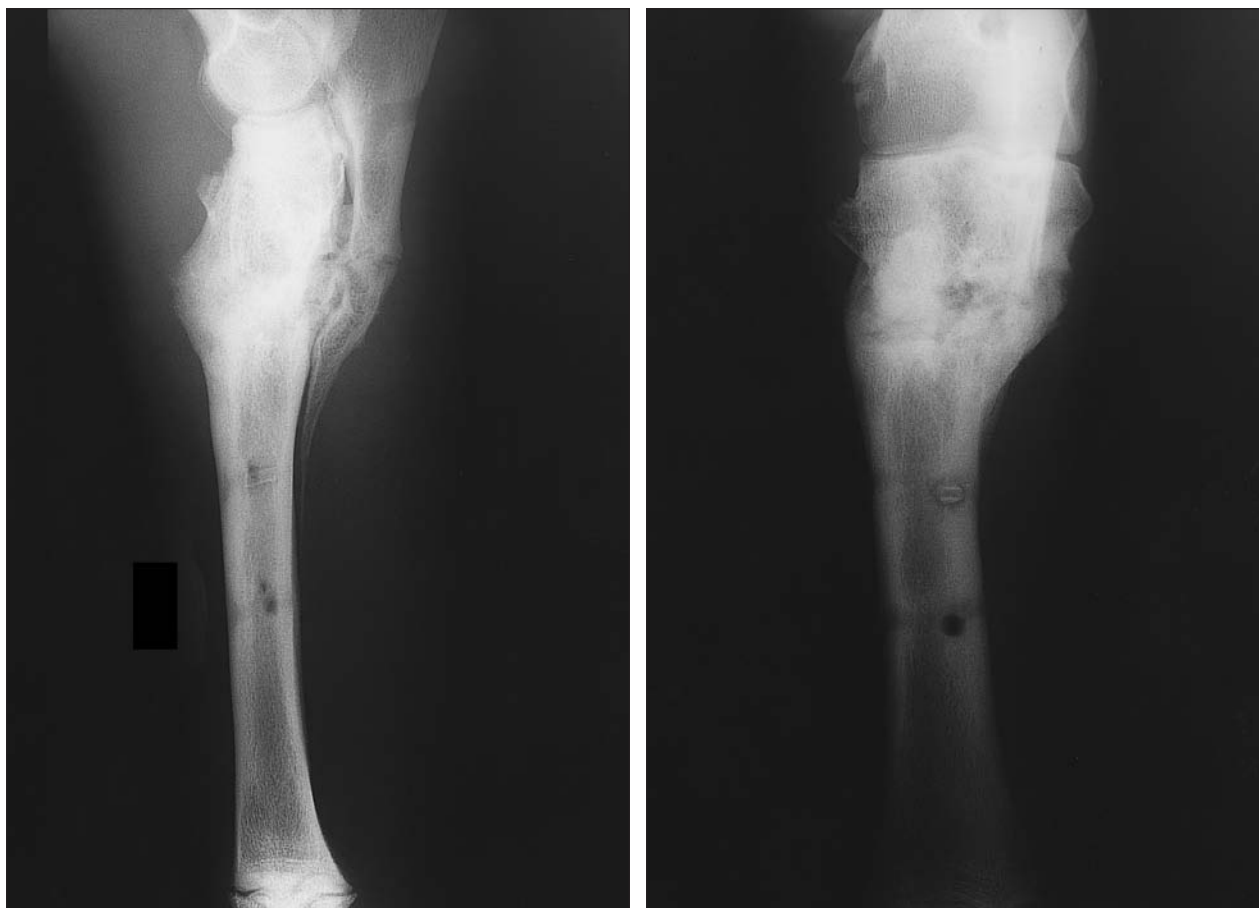


Figure 4—Lateromedial (left) and craniocaudal (right) radiographic projections of the left elbow joint and antebrachium of the donkey in Figure 2 76 days after surgery.

well the donkey tolerated the distraction. If the motor was difficult to rotate or the donkey demonstrated any signs of discomfort during distraction, indicating excessive soft-tissue tension, the rate was not altered. Distraction rates reported in the literature have been found to be influenced by age.^{1,2} Using the parameters described and periodic radiographic evaluation, our distraction rate was similar to those used in previous studies. Because the proximal ring and pins were placed parallel to the elbow joint and the distal pins and rings were placed perpendicular to the radius, correction was considered complete when the proximal and distal rings were parallel.

Angular limb deformities in horses can be a result of perinatal or developmental factors. Perinatal factors include incomplete ossification of the carpal or tarsal bones, resulting in deformation of those structures and periarticular laxity of the supporting soft tissues.³ Developmental factors include disproportionate physal growth secondary to nutritional imbalances and traumatic physitis secondary to excessive exercise or trauma (eg, physal fractures).³ Severe deformities in young growing animals can be surgically corrected by means of hemicircumferential periosteal transection and elevation with or without transphysal bridging. This method relies on the remaining inherent growth at the physis for correction of the deformity and is not effective in young animals such as the donkey

described in the present report that have sustained sufficient trauma to the physis to result in premature physal closure. In addition, in animals with severe chronic deformities, contracture of the surrounding soft tissues becomes a concern.^{4,7}

Numerous techniques for surgical correction of angular limb deformities in older animals and in animals with premature physal closure have been described.^{3,8} These techniques typically involve internal fixation of any 1 of various types of osteotomy. Types of osteotomies described for correction of angular limb deformities include a closing wedge osteotomy, a dome osteotomy, a step osteotomy in the sagittal plane, and a step osteotomy in the frontal plane. Closing wedge and dome osteotomies are technically simple to perform; however, because the osteotomy typically has to be performed at the level of the physis, leaving little bone between the physis and the nearest joint, stabilizing the osteotomy by use of internal fixation devices is often difficult. A closing wedge osteotomy also results in a loss of limb length. Step osteotomies allow for fixation distant from the pivot point, which makes application of internal fixation devices for stable fixation easier and may allow for application of interfragmentary compression. They also preserve limb length.³

In the donkey described in the present report, the close proximity between the point of maximal deformity and the elbow joint, the severity of the val-

gus deformity, and the amount of soft-tissue contraction would have made use of techniques requiring internal fixation difficult. The small amount of epiphyseal bone between the joint and the angular deformity at the level of the physis would have made it impossible to obtain optimal fixation (engagement of 6 to 8 cortices) with dynamic compression plates. In addition, although use of a specialty plate such as a dynamic condylar screw plate, an angle blade plate, or a cobra head plate may have allowed for stable internal fixation,⁹⁻¹⁵ their inability to safely correct the angular deformity acutely without stretch injury to the tendons and neurovascular structures negated their use.

Use of external skeletal fixation such as transfixation casts and external skeletal fixators for repair of fractures in horses has been reported.¹⁶⁻²¹ However, these techniques can only be used for distal long bone and phalangeal fractures in the lower limbs of horses. Use of type-II and -III external skeletal fixators, similar to those used in small animals, has been studied in horses but has met with limited success. In addition, to our knowledge, use of an external skeletal fixator for correction of an angular limb deformity in a horse has not been reported.

Ilizarov developed the external ring fixator in 1951 and, subsequently, developed the concept of distraction osteogenesis under the law of tension-stress. The law of tension-stress states that gradual traction on living tissues creates stresses that stimulate and maintain regeneration and active growth of certain tissue structures.^{1,5-7,22} There is also evidence that tension stimulates proliferation of cells and cellular components of blood vessels, skeletal muscle, smooth muscle, and nervous tissue as well as bone.^{4,5} Since their development, external ring fixators have been used extensively in human medicine for the correction of congenital and acquired limb deformities. They have also been used for limb lengthening in patients with dwarfism or severe limb deformities and to preserve limb length following tumor resection.

Successful use of an external ring fixator for repair of a metacarpal fracture in a 100-kg (220-lb) Arabian foal has been reported.²³ The external ring fixator described in the present report satisfied all the requirements for a successful repair in this donkey. Because of the donkey's small size, the ring fixator provided stable fixation of the osteotomy site, and the ability to use hinge rods and the angular motor assembly on the fixator allowed for slow controlled distraction of the osteotomy site and surrounding soft tissues. We believe that use of an external ring fixator should be considered in equids with severe chronic angular limb deformities that are not amenable to correction by previously described techniques requiring internal fixation.

^aAdjustable hinged Ilizarov external ring fixator, IMEX Veterinary Inc, Longview, Tex.

^bZimmer pneumatic oscillating saw, Zimmer/Schaffer Assoc, Birmingham, Ala.

References

1. Yanoff SR, Hulse DA, Palmer RH, et al. Distraction osteogenesis using modified external fixation devices in five dogs. *Vet Surg* 1992;21:480-487.
2. Aronson J, Shen X. Experimental healing of distraction osteogenesis comparing metaphyseal with diaphyseal sites. *Clin Orthop* 1994;301:25-30.
3. Auer JA. Appendicular deviations. In: White NA II, Moore JN, eds. *Current practice of equine surgery*. Philadelphia: JB Lippincott Co, 1990;482-500.
4. Elkins AD, Morandi M. The Ilizarov external ring fixator: principles, techniques, and uses. In: Slatter D, ed. *Textbook of small animal surgery*. Philadelphia: WB Saunders Co, 1993;1656-1661.
5. Ilizarov GA. The tension-stress effect on the genesis and growth of tissues, part I. The influence of stability of fixation and soft tissue preservation. *Clin Orthop Rel Res* 1989;238:249-281.
6. Ilizarov GA. The tension-stress effect on the genesis and growth of tissues, part II. The influence of the rate and frequency of distraction. *Clin Orthop Rel Res* 1989;239:263-285.
7. Marcellin-Little DJ, Ferretti A, Roe SC, et al. Hinged Ilizarov external fixation for correction of antebrachial deformities. *Vet Surg* 1998;27:231-245.
8. Auer JA. Angular limb deformities. In: Auer JA, ed. *Equine surgery*. Philadelphia: WB Saunders Co, 1992;940-956.
9. Auer JA. Application of the dynamic condylar screw (DCS) and dynamic hip screw (DHS) implant systems in the horse. *Vet Comp Orthop Traumatol* 1988;1:1-8.
10. Auer JA. Surgical equipment and implants for fracture repair. In: Nixon A, ed. *Equine fracture repair*. Philadelphia: WB Saunders Co, 1996;52-62.
11. Auer JA. Principles in fracture treatment. In: Auer JA, ed. *Equine surgery*. Philadelphia: WB Saunders Co, 1992;812-833.
12. Honnas CM. Surgical treatment of selected musculoskeletal disorders of the forelimb. In: Auer JA, ed. *Equine surgery*. Philadelphia: WB Saunders Co, 1992;985-1054.
13. Frauenfelder HC, Fessler JF. Proximal radius fracture in a horse: angle blade plate repair. *Vet Surg* 1981;10:96-100.
14. Hunt DA, Snyder JR, Morgan JP, et al. Femoral capital physal fractures in 25 foals. *Vet Surg* 1990;19:41-49.
15. Kirker-Head CA, Fackelman GE. Use of the cobra head bone plate for distal long bone fractures in large animals. *Vet Surg* 1989;18:227-234.
16. Cervantes C, Madison JB, Miller GJ, et al. An in vitro biomechanical study of a multiplanar circular external fixator applied to equine third metacarpal bones. *Vet Surg* 1996;25:1-5.
17. Nixon AJ, Watkins JP, Auer JA. Principles of fracture fixation. In: Nixon AJ, ed. *Equine fracture repair*. Philadelphia: WB Saunders Co, 1996;63-86.
18. Nunamaker DM, Richardson DW, Butterweck DM, et al. A new external skeletal fixation device that allows immediate full weightbearing application in the horse. *Vet Surg* 1986;15:345-355.
19. Richardson DW, Nunamaker DM, Sigafos RD. Use of an external skeletal fixation device and bone graft for arthrodesis of the metacarpophalangeal joint in horses. *J Am Vet Med Assoc* 1987;191:316-321.
20. Sullins KE, McIlwraith CW. Evaluation of 2 types of external skeletal fixation for repair of experimental tibial fractures in foals. *Vet Surg* 1987;16:255-264.
21. Wisner AB. Full Kirschner splint repair of a fractured radius in a foal. *Vet Med Small Anim Clin* 1980;75:1045-1047.
22. Richards M, Goulet JA, Weiss JA, et al. Bone regeneration and fracture healing. Experience with distraction osteogenesis model. *Clin Orthop Rel Res* 1998;355S:S191-S204.
23. Jukema GN, Settner M, Dunkelmann G, et al. High stability of the Ilizarov ring fixator in a metacarpal fracture of an Arabian foal. *Arch Orthop Trauma Surg* 1997;116:287-289.